DEPARTMENT OF THE ARMY
UNITED STATES ARMY AVIATION TEST BOARD
Fort Rucker, Alabama 36360

STEBG-TD (6) APR 7 1967

SUBJECT: Letter Report, Product Improvement Test of T53-L-11 Engine, RDT&E Project No. _____, USATECOM Project No. 4-5-0101-01 and -06

(9) Letter rept. (16) USATECOM-4-5-0101-01, USATECOM-4-5-0101-06

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1. References.

a. Letter, Lycoming Division of AVCO Corporation, 9 April 1965, subject: "CY 1964 Product Support and Product Improvement T53-L-11 Engine."

b. Message, 5-1168, AMCPM-IR-T, Commanding General, US Army Materiel Command, 17 May 1965, subject: "Product Improved T53-L-11 Engine S/N LE-09753."

c. Letter, AMSTE-BG, Headquarters, US Army Test and Evaluation Command, 1 June 1965, subject: "Test Directive, USATECOM Project No. 4-5-0101-( ), Product Improvement Test, UH-1B Items."

d. Letter, SMOSM-EAA, Headquarters, US Army Aviation Materiel Command, 11 June 1965, subject: "Product Improvement Test, UH-1B Helicopter."

e. Project Transcript Sheet, AMSTE-BG, Headquarters, US Army Test and Evaluation Command, 18 June 1965, "USATECOM Project No. 4-5-0101-01, Product Improvement Test of T53-L-11 Engine S/N LE-09753."

f. Letter, Lycoming Division of AVCO Corporation, 24 June 1965, subject: "Recommended Plan of Test for Manual Acceleration Control."

g. Plan of Test, USATECOM Project No. 4-5-0101-( ), "UH-1B Product Improvement Test," US Army Aviation Test Board, 8 October 1965.

h. Project Transcript Sheet, AMSTE-BG, Headquarters, US Army Test and Evaluation Command, 18 October 1965, "USATECOM Project No. 4-5-0101-06, Evaluation of Product Improvement Items in T53-L-11 Engine, S/N LE-09753."

i. Letter, STEBG-TP-A, US Army Aviation Test Board, 19 October 1965, subject: "Iroquois Test Coordination Meeting."

j. Final Report of Test, USATECOM Project No. 4-5-0151-01, "Product Improvement Test of T53-L-11 Engine in the UH-1D Helicopter," US Army Aviation Test Board, 7 April 1966.

k. Technical Manual 55-1520-211-35, "DS, GS, and Depot Maintenance Manual, Army Models UH-1A and UH-1B Helicopters," 13 June 1966, with change 1, 20 September 1966.

l. Technical Bulletin 55-2800-200-30/1, "T53 Engine Inspection Guide, Aircraft Engine Models T53-L-3/5/7/9/9A/11," 28 June 1966.

m. Letter Report, "Product Improvement Test of the T53-L-11 Engine (Operational Suitability Testing of the Manual Acceleration Control), USATECOM Project No. 4-5-0101-01," US Army Aviation Test Board, 7 October 1966.

n. Message, AMC 53674, AMCPM-IR-T, Commanding General, US Army Materiel Command, 26 January 1967, subject: "Manual Acceleration Fuel Control, USATECOM Project No. 4-5-0101-01."

o. Plan of Test, USATECOM Project No. 4-5-0151-01, "Product Improvement Test of T53-L-11 Engine Product Improvement Items." US Army Aviation Test Board, undated.

2. Background.

a. Product improvement of the UH-1( ) helicopter has been and is continuous process. To reduce cost and weight and to increase service life, certain components of the T53-L-11 gas turbine engine have been modified.

b. Several product-improvement items were tested in engine, S/N LE-06005X, during the Product Improvement Test of T53-L-11 Engine in the UH-1D Helicopter, USATECOM Project No. 4-5-0151-01 (reference j). That engine was removed after 941 test hours because of failure of the number four bearing, which was not a test item. To provide more statistical samples and to obtain results from 1200 test hours, items comparable to those previously tested and certain other items were installed on T53-L-11 engine, S/N LE-09753, and entered into the product-improvement test program.

3. Description of Materiel.

a. Modified Manual Fuel Control, P/N 83000. The fuel control programs the flow of fuel to the engine, operating in either the automatic or emergency mode. In the automatic mode, fuel flow is varied by changes in power demand, pressure, and ambient temperature to maintain power turbine speed. In the emergency mode, fuel flow is controlled by the position of the throttle twist grip. A pressure unit has been incorporated which senses compressor discharge pressure and positions a fuel metering valve to regulate the fuel flow. An electrically-operated air bleed valve provides continuous open-bleed-band operation while the fuel control is being operated in the emergency mode. These modifications regulate the fuel flow and slow the acceleration rate during emergency mode operation.

b. Gas Producer Turbine Wheel (Thicker-Walled Blades), FSN 2840-022-7501, P/N 1-100-490-06. The gas producer (N_1) turbine wheel is mechanically coupled to and drives the compressor. The modified assembly incorporates thicker-walled turbine blades by reducing the hollow core area of each blade.

c. Combustor Deflector (Flexible Support), FSN 2840-872-6126, P/N 1-110-440-02. The combustor deflector located in the combustion section deflects the gas stream 180 degrees into the gas producer (N_1) nozzle. The modified deflector incorporates a bellows type insert, in the center section, which provides flexibility to the assembly.

d. Power Turbine Wheel (N_2) FSN 2840-475-6948, P/N 1-140-210-11. The power turbine wheel is driven by gases received from the power turbine nozzle and drives the output gearing. The modified turbine wheel incorporates turbine blades which have been subjected to an extensive, controlled heat treat cycle prior to installation.

e. Main Shaft Bearings (Number Two and Number Three Position), FSN 3110-869-7151, P/N 1-300-014-05 (SKF-457798). The number two main shaft bearing is the support bearing for the rear of the compressor and for the gas producer (N_1) turbine assembly. The number three main shaft bearing is the support bearing for the power (N_2) turbine assembly. The modified bearings incorporate an AMS 6415 steel silver flashed cage with a modified pocket angle.

f. Compressor Rotor Assembly, P/N 1-100-560-07. The assembly consists of five axial stages and one centrifugal stage. The assembly draws air through the inlet, and delivers compressed air to the combustor and the bleed ports. The modified assembly incorporates axial stage compressor blades constructed of AMS 350 stainless steel, and a fifth-stage axial disc constructed of titanium.

g. Power Turbine Nozzle (Depot Repairable), P/N 1-140-420-04-E (EXP-7710-02). The power turbine nozzle receives gases under high pressure and velocity from the gas producer (N_1) turbine and redirects these gases at the correct angle to the power turbine wheel (N_2).

h. Fuel Vaporizers, FSN 2915-074-3369, P/N 1-130-590-02. Eleven fuel vaporizers located in the combustion chamber introduce fuel under pressure. The vaporizers incorporate an improved weld at the base of the tube, a cooling shroud to provide air to the weld at the base of the tube, an an improved attaching weld for the cooling shroud.

i. Combustor Liner Mounting Studs (Flexible and Three-Point-Solid Suspension System), FSN 5306-908-0373, P/N 1-130-096-02 and FSN 5306-908-0374, P/N 1-130-096-03. The combustor liner is held in place in the combustion chamber by eleven beveled mounting studs arranged in a circular pattern. Eight of the studs have shoulders to provide some flexibility to the liner. Three of the studs, located 120 degrees apart, do not have shoulders and provide solid suspension of the combustor liner at three equidistant points.

j. Combustor Liner, FSN 2840-907-0853, P/N 1-130-600-02. The combustor liner is located in the combustion chamber and provides an inclosed area for combustion. The liner incorporates mounting brackets modified to accept the beveled mounting studs.

k. Air Seal Segments (Increased Length), FSN 2840-736-3996, P/N 1-140-222-01. Twelve air seal segments are installed to retain the asbestos gas seal in the power turbine nozzle retention assembly. The modified segments have been increased in length.

l. Gas Producer (N_1) Tachometer Drive Seal, FSN 5330-855-8361, P/N 4238X. The N_1 tachometer drive seal is located in the accessory gear box and provides a tight seal around the tachometer drive to prevent the leakage of oil from the gear box. The modified seal is constructed of nine butted segments.

4. Test Objective.

To determine the durability of the modified manual acceleration control and the suitability of the other test items.

5. Method. The test items were subjected to 1200 flight hours (except as indicated in paragraph 6) with the test-bed helicopter at maximum gross weight. All takeoffs were performed at a minimum of 40 pounds per square inch (p.s.i.) torque when other engine limits were not exceeded. Engine performance and wear were monitored by use of a photo panel, an engine vibration meter, and oil analysis. Visual inspections of the test items were conducted on a scheduled and an as-

necessary basis. The condition and cause of failure of any test item failing during the test period were reported. The condition of all test items completing the test was reported. The analytical inspection of each test item was sufficiently detailed to ascertain whether the test item corrected the problem for which it was designed.

6. Discussion.

a. The test items were initially installed in engine S/N LE-09753. After 192.7 hours of operation, the compressor of this engine suffered foreign object damage (FOD), necessitating engine removal. Removal of the engine resulted in termination of the test of the No. 2 main shaft bearing, the compressor rotor assembly, and the gas producer (N_1) tachometer drive seal. The other test items were installed in engine, S/N LE-10394, to continue the test. At 600.4 test hours, FOD was found in the compressor section of engine, S/N LE-10394. The remaining test items were then installed in engine, S/N LE-09109, and the test was continued to 1200 test hours.

b. At 227.9 test hours, the modified manual fuel control was removed from engine, S/N LE-10394, and returned to the manufacturer because of fluctuations in the gas producer turbine speed, power turbine speed, and torque pressure. The manufacturer failed to locate the problem and returned the fuel control to the USAAVNTBD. The fuel control was then installed on engine, S/N LE-09109, but no test time was acquired because the engine would not accelerate with the fuel control in manual mode and the helicopter cabin heat and anti-icing airbleeds on. The fuel control was again returned to the manufacturer, who located and solved the problem. Upon return of the fuel control to the USAAVNTBD, durability testing was continued with three different engines, S/N's LE-09056, LE-10633, and LE-06005XA, until terminated at 589.1 test hours because of FOD to engine S/N LE-06005XA.

7. Summary of Results. See inclosure for Engineering Analysis.

a. Modified Manual Fuel Control. After the problem occurring at 227.9 test hours was corrected (paragraph 6b), the fuel control operated satisfactorily until termination of the test at 589.1 test hours.

b. Gas Producer Turbine Wheel (Thicker Walled Blades). The gas producer turbine wheel operated 1200.0 hours. No blade cracks developed.

c. Combustor Deflector (Flexible Support). The combustor deflector accumulated 1200.0 hours. No cracking in the seam weld developed.

d. Power Turbine Wheel (N_2). The power turbine wheel operated 1200.0 hours with no blade-tip clearance problems.

e. Main Shaft Bearings (Number Two and Number Three Position). The No. 2 position main shaft bearing operated 192.7 hours and was in serviceable condition upon disassembly. The No. 3 position main shaft bearing operated 1200.0 hours with no discrepancies.

f. Compressor Rotor Assembly. The compressor assembly operated 192.7 hours prior to removal because of FOD (paragraph 6). Except for the FOD, the blades were in good condition, and the fifth-stage titanium disc was in good condition.

g. Power Turbine Nozzle (Depot Repairable). The power turbine nozzle accumulated 1200.0 hours. Some vane-to-shroud joint cracking occurred but it was within the limits specified in the Technical Manual (TM) (reference k).

h. Fuel Vaporizer. Seven of the original eleven fuel vaporizers operated 1200.0 hours with damage still within TM limits. Two of the eleven operated 1200.0 hours with the damage at 1200.0 hours exceeding TM limits. The remaining two vaporizers operated 600.4 hours prior to being replaced for excessive tip cracking and burning. No cracking occurred in the base weld and the cooling shrouds remained intact on all eleven original vaporizers.

i. Combustor Liner Mounting Studs (Flexible and Three-Point-Solid Suspension System.) The combustor liner mounting studs accumulated 1200.0 hours. No chafing or cracking developed.

j. Combustor Liner. The combustor liner accumulated 1200.0 hours. No cracking of the stud mounting brackets occurred.

k. Air Seal Segments (Increased Length). The air seal segments were in good condition after 1200.0 hours.

l. Gas Producer (N_1) Tachometer Drive Seal. The drive seal accumulated 192.7 hours prior to removal of the compressor/reduction gear section because of FOD (paragraph 6). The seal was in good condition.

8. Conclusions.

a. Insufficient operating time has been accumulated to determine the durability of the Modified Manual Fuel Control, P/N 83000.

b. On the basis of one test sample of each, the following engine components are suitable for use in the T53-L-11 engine and offer improvement over the earlier developed components:

Nomenclature	FSN	P/N
Gas Producer Turbine Wheel	2840-022-7501	1-100-490-06
Combustor Deflector	2840-872-6126	1-110-440-02
Power Turbine Wheel	2840-475-6948	1-140-210-11
No. 3 Main Shaft Bearing	3110-869-7151	1-300-013-05
Power Turbine Nozzle	Not available	1-140-420-04-E (EXP-7710-02)

Nomenclature	FSN	P/N
Fuel Vaporizer	2915-074-3369	1-130-590-02
Combustor Liner Mounting Studs	5306-908-0373	1-130-096-02
	5306-908-0374	1-130-096-03
Combustor Liner	2840-907-0853	1-130-600-02
Air Seal Segments	2840-736-3996	1-140-222-01

c. Insufficient operating time has been accumulated to determine suitability of the following engine components:

Nomenclature	FSN	P/N
No. 2 Main Shaft Bearing	3110-869-7151	1-300-013-05
Rotor Assembly, Compressor	Not available	1-100-560-07
Gas Producer (N_1) Tachometer Drive Seal	5330-855-8361	4238X

9. Recommendations. It is recommended that:

a. Additional Phase F testing be performed on the Modified Manual Fuel Control, P/N 83000, to determine its durability, if the control is to be adopted as standard for the T53-L-11 engine.

b. On the basis of one test sample of each, the following components be adopted as standard for the T53-L-11 engine:

Nomenclature	FSN	P/N
Gas Producer Turbine Wheel	2840-022-7501	1-100-490-06
Combustor Deflector	2840-872-6126	1-110-440-02

STEBG-TD
SUBJECT: Letter Report, "Product Improvement Test of T53-L-11 Engine," RDT&E Project No. _____, USATECOM Project No. 4-5-0101-01 and -06

Nomenclature	FSN	P/N
Power Turbine Wheel	2840-475-6948	1-140-210-11
No. 3 Main Shaft Bearing	3110-869-7151	1-300-013-05
Power Turbine Nozzle	Not available	1-140-420-04-E (EXP-7710-02)
Fuel Vaporizer	2915-074-3369	1-130-590-02
Combustor Liner Mounting Studs	5306-908-0373 5306-908-0374	1-130-096-02 1-130-096-03
Combustor Liner	2840-907-0853	1-130-600-02
Air Seal Segments	2840-736-3996	1-140-222-01

c. Additional Phase F testing be performed on the following components to determine their suitability for operation in the T53-L-11 engine:

Nomenclature	FSN	P/N
No. 2 Main Shaft Bearing	3110-869-7151	1-300-013-05
Rotor Assembly, Compressor	Not available	1-100-560-07
Gas Producer (N_1) Tachometer Drive Seal	5330-855-8361	4238X

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ENGINEERING ANALYSIS

1. Introduction.

a. Twelve product improvement components began test in T53-L-11 engine, S/N LE-09753. After this engine had operated 192.7 hours the compressor suffered foreign object damage (FOD), which necessitated engine removal. Removal of the engine resulted in termination of the test of the:

Nomenclature	FSN	P/N
Number 2 Main Shaft Bearing	3110-869-7151	1-300-013-05
Compressor Rotor Assembly	Not available	1-100-560-07
Gas Producer (N_1) Tachometer Drive Seal	5330-855-8361	4238X

b. The following components, after analytical inspection, were installed in T53-L-11 engine, S/N LE-10394:

Nomenclature	FSN	P/N
Gas Producer Turbine Wheel	2840-022-7501	1-100-490-06
Combustor Deflector	2840-872-6126	1-110-440-02
Power Turbine Wheel	2840-475-6948	1-140-210-11
Number 3 Main Shaft Bearing	3110-869-7151	1-300-013-05
Power Turbine Nozzle	Not available	1-140-420-04-E (EXP-7710-02)
Fuel Vaporizers	2915-074-3369	1-130-590-02
Combustor Liner Mounting Studs	5306-908-0373 5306-908-0374	1-130-096-02 1-130-096-03
Combustor Liner	2840-907-0853	1-130-600-02
Air Seal Segments	2840-736-3996	1-140-222-01

INCLOSURE

After these components accumulated 600.4 test hours, engine S/N LE-10394 was removed, and the combustion section was disassembled for inspection of the PIP components. During this inspection, FOD was found in the compressor of the engine; as a result, the nine PIP components were, after inspection, installed in T53-L-11 engine, S/N LE-09109.

c. After completion of the remaining 599.6 test hours, the combustion section of engine S/N LE-09109 was disassembled for an analytical inspection. The results of this final inspection and the intervening inspections are summarized in paragraph 2.

d. In addition to the components listed in paragraphs a and b above, the modified manual fuel control, P/N 83000, was instatted at various times during the test period. (See paragraph 2a for details.)

e. A photopanel was used to monitor engine performance during the test period. Difficulties were experienced with the instrumentation package during the early portion of the test; therefore, a complete performance history is not available. The difficulty of performance analysis was further increased by the use of three different compressor sections with the test combustion section. Analysis indicates, however, that of the three parameters being monitored (shaft horsepower, fuel flow, and exhaust gas temperature), the only significant change in performance during the test was an increase in exhaust gas temperature. As can be seen in figure 1, the major portion of the temperature rise occurred during the period of time between 632.9 and 1095.3 combustion section hours. This was while the combustion section was on engine S/N LE-09109 (8 April 1966 to 18 July 1966). The major cause of the increased exhaust gas temperature was erosion of the first stage turbine (gas producer) and its accompanying flange.

f. During the test period vibration readings were recorded on a daily basis at the following gas producer/power turbine speeds:

Gas Producer Speed (percent)	Power Turbine Speed (r.p.m.)
90	6200
75	6400
85	6400
90	6400
90	6600

The locations of the vibration probes and the filters used were as specified in paragraph 5-34, Chapter 5, Section II, of TM 55-1520-211-35, dated 13 June 1966. No excessive vibrations were noted during the test. The FOD to the compressor did not manifest itself in the amplitude of vibrations experienced by the engine. The only noticeable change in engine vibration level was a decrease in the amplitude of the vibrations recorded from the No. 3 probe. This probe was mounted on the oil scavenge line adapter at the exhaust diffuser. The decrease in vibration amplitude was detected when the test combustion section was installed on engine S/N LE-10394. The order of reduction was from an average of 0.90 mils to an average of 0.45 mils. The cause of the 50 percent drop in vibration amplitude cannot be explained.

2. Discussion.

a. Modified Manual Fuel Control, FSN Not Avialable, P/N 83000, S/N 642AP1.

(1) The modified manual fuel control (figure 2) was originally installed on engine S/N LE-09753 and was later installed on engine S/N LE-10394. After 227.9 hours the control was removed and returned to the engine manufacturer because of fluctuations in the gas producer turbine speed, power turbine speed, and torque pressure. The engine manufacturer reported that bench and flight tests failed to duplicate the fluctuations, and the control was returned to the USAAVNTBD. The control was reinstalled, but no test time was acquired because the engine would not accelerate in the manual mode when helicopter cabin heat and anti-icing airbleeds were on. Bench test at the engine manufacturer's facility revealed that the control was still serviceable with all flow schedules the same as when initially shipped. Flight testing by the engine manufacturer, however, confirmed the malfunction. Subsequent investigation revealed that the problem was with the compressor discharge pressure input to the manual control actuator. This pressure was being tapped off at the point where the airbleed actuator takes its pressure from the airbleed manifold inside the air diffuser. When all bleeds were on, the compressor discharge pressure decreased enough to hamper operation of the manual control. To prevent recurrence of this problem, the air pressure tap was moved to one of the instrumentation ports on the air diffuser. This rerouting of the pressure tap solved the problem, and the fuel control was returned to the USAAVNTBD.

(2) Durability testing was continued with the fuel control installed on engines as indicated below.

Date Installed	Engine S/N	Date Removed	Test Hours This Installation	Total Test Hours Accumulated
19 Aug 66	LE-09056	4 Sep 66	15.8	243.8
4 Sep 66	LE-10633	7 Oct 66	208.2	452.0
22 Dec 66	LE-06005XA	24 Jan 67	137.1	589.1

Engine S/N LE-06005XA suffered FOD when the fuel control had accumulated 589.1 test hours, and USAAVCOM terminated the durability test on 27 January 1967.

b. Gas Producer Turbine Wheel (Thicker-Walled Blades), FSN 2840-022-7501, P/N 1-100-490-06. The gas producer turbine wheel (figure 3) accumulated 192.7 hours in engine S/N LE-09753. After the engine was removed due to FOD, the turbine wheel was fluorescent-penetrant inspected and no defects were found. The gas producer turbine tip clearances were:

Position	12:00	1:30	3:00	4:30	6:00	7:30	9:00	10:30
Clearance (Inch)	0.028	0.029	0.028	0.028	0.032	0.028	0.027	0.033

(Minimum acceptable clearance is 0.025 inch)

The turbine wheel was then installed in engine S/N LE-10394. After accumulating 600.4 hours, the wheel was removed for an inspection, which revealed no discrepancies. Since the compressor of engine S/N LE-10394 had FOD, the turbine wheel was installed in engine S/N LE-09109. After accumulating 1200.0 hours, the turbine wheel was again fluorescent-penetrant inspected, and no cracks were evident. Moderate to heavy erosion was found on the leading edge outer blade tips (figure 4). The gas producer turbine tip clearances were:

Position	12:00	1:30	3:00	4:30	6:00	7:30	9:00	10:30
Clearance (Inch)	0.034	0.042	0.040	0.042	0.055	0.042	0.043	0.042

(Minimum acceptable clearance is 0.025 inch)

The large tip clearances were a result of erosion of the turbine blade tips and the nozzle flange. The turbine wheel was suitable for further testing. The manufacturer, however, stated that the GMR blade material has a life limit of 1200 to 1500 hours, so further operation with the test turbine wheel was not feasible. Since these turbine blades were designed to reduce the incidence of cracking and no blade cracks occurred during the 1200.0 test hours, the new gas producer turbine wheel appears to be a significant improvement over the previous assembly, FSN 2840-855-9480, P/N 1-100-490-04.

c. Combustor Deflector (Flexible Support), FSN 2840-872-6126, P/N 1-110-440-02. The combustor deflector (figure 5) was removed after accumulating 192.7 hours in engine S/N LE-09753. Inspection revealed no defects. The deflector was installed in engine S/N LE-10394. After accumulating 600.4 hours, the deflector was again removed for inspection. No defects were evident and the deflector was installed in engine S/N LE-09109. After accumulating 1200.0 hours, inspection revealed no major defects. Only minor cracking was present in the inner flange spot welds (figure 6). Since the curl did not crack circumferentially at the seam weld, the new deflector appears to be a significant improvement over the previous assemblies, FSN's 2840-793-2065 and 2840-064-9425, P/N's 1-110-020-02 and -06, respectively.

d. Power Turbine Wheel (N_2), FSN 2840-475-6948, P/N 1-140-210-11. The power turbine wheel (figure 7) was removed from engine S/N LE-09753 after operating 192.7 hours. Fluorescent-penetrant inspection disclosed the wheel to be free of cracks. Power turbine wheel tip clearances were:

Position	12:00	1:30	3:00	4:30	6:00	7:30	9:00	10:30
Clearance (Inch)	0.036	0.036	0.033	0.032	0.034	0.032	0.032	0.032

(Minimum acceptable clearance is 0.025 inch)

The wheel was installed in engine S/N LE-10394. After operating 600.4 hours, the wheel was removed for inspection. Inspection revealed no cracks or other discrepancies, and the wheel was then installed in engine S/N LE-09109. After operating 1200.0 hours, the wheel was again removed for inspection. Fluorescent-penetrant inspection disclosed no cracks; however, 22 of the 62 blades had FOD. Tip clearances were:

Position	12:00	1:30	3:00	4:30	6:00	7:30	9:00	10:30
Clearance (Inch)	0.042	0.042	0.040	0.038	0.037	0.037	0.040	0.041

(Minimum acceptable clearance is 0.025 inch)

Inspection at the manufacturer's facility revealed the wheel diameter to be 0.006 inch over blueprint. The usual blade growth period occurs during "Green Run" at the factory. No tip clearance problems were observed during this test, and since blade growth was minimal and actually compensated for by normal power turbine cylinder wall erosion, the new power turbine wheel with the aged blades appears to offer an improvement over the turbine wheels with non-aged blades.

e. *Main Shaft Bearings (Number Two and Three Position),* FSN 3110-869-7151, P/N 1-300-013-05 (SKF-457798). After accumulating 192.7 hours in engine S/N LE-09753, the No. 2 bearing (figure 8) was removed as a portion of the compressor section. Inspection revealed that the roller pockets had not developed cracks, and the rollers and races were in good condition. The No. 3 main shaft bearing was operated for a total of 1200 hours in engines S/N's LE-09753, LE-10394, and LE-09109. Magnetic particle inspection revealed no cracks, and the rollers and races were in good condition. The cage cracking phenomena has been associated more with the No. 2 bearing than with the No. 3. Because of the short operating time of this bearing in the No. 2 position, no conclusions can be drawn. The new bearing is acceptable for the No. 3 position in lieu of bearing, FSN 3110-863-1237, P/N 1-300-013-04.

f. Compressor Rotor Assembly, FSN Not Available, P/N 1-100-560-07. After accumulating 172.0 hours, engine S/N LE-09753 was returned to the engine manufacturer for magnetic particle inspection of the AMS 350 stainless steel compressor blades, FSN not available, P/N 1-100-381-01 through -385-01. This inspection was dictated

by the appearance of cracks in similar blades at the manufacturer's plant. The inspection revealed one blade in the fifth stage to be cracked. The defective blade was replaced, the compressor rebalanced, and the engine returned to the USAAVNTBD. After accumulating 20.7 more hours for a total time of 192.7 hours, the engine experienced FOD (figures 9 and 10). The combustion section was removed and installed on engine S/N LE-10394. Inspection of the compressor revealed that, except for the FOD, the blades were in good condition. Insufficient time, however, had been accumulated to determine their susceptibility to erosion. Inspection of the titanium fifth-stage disc, FSN 2840-924-7362, P/N 1-100-417-03, revealed it to be in serviceable condition, with no cracking evident. Insufficient time was accumulated to determine its suitability.

g. Power Turbine Nozzle (Depot Repairable), FSN Not Available, P/N 1-140-420-04-E (EXP-7710-02). The power turbine nozzle (figure 11) accumulated 192.7 hours in engine S/N LE-09753 prior to the first inspection. Fluorescent-penetrant inspection revealed that eleven of the vanes had cracks in the vane-to-outboard shroud joint at the trailing edge (figure 12). The cracks varied in length from 0.031 to 0.062 inch. The nozzle was installed in engine S/N LE-10394 and accumulated 600.4 hours prior to the next inspection. This inspection revealed no additional discrepancies and the nozzle was installed in engine S/N LE-09109. After operating for 1200 hours, the nozzle was again inspected. Dye-penetrant inspection revealed that 18 vanes had cracks in the vane-to-outboard shroud joint at the trailing edge (similar to those shown in figure 12); 4 vanes had cracks in the vane-to-inboard shroud joint at the trailing edge; 20 vanes had cracks in the vane-to-outboard shroud joint at the leading edge; and 1 vane had a crack in the vane-to-inboard shroud joint at the leading edge. All cracks were within the field limits specified in TB 55-2800-200-30/1 dated 28 June 1966. On the basis of these facts, the new nozzle appears acceptable for use in the T53-L-11 engine.

h. Fuel Vaporizers, FSN 2915-074-3369, P/N 1-130-590-02. The fuel vaporizers (figure 13) operated 192.7 hours in engine S/N LE-09753. Inspection revealed that one vaporizer had 1/16-inch cracks in two of the four welds that attach the cooling shroud to the vaporizer (figure 14), and another vaporizer had slightly damaged threads (figure 15). All vaporizers were considered serviceable and were installed in engine S/N LE-10394. After 600.4 hours of operation, the vaporizers were again inspected. Two vaporizers, numbers 2 and 4, were replaced

due to tip cracking and burning in excess of 0.75 inch (criteria per TB 55-2800-200-30/1) (figure 16). Because of the nonavailability of P/N 1-130-590-02 vaporizers, P/N 1-130-590-01 and -01"A" vaporizers were installed in lieu of the removed vaporizers. The original nine vaporizers and the two new vaporizers were installed in engine S/N LE-09109. After the original nine vaporizers had accumulated 1200 hours, they were again inspected. Inspection revealed that two of the nine vaporizers (positions 1 and 11) had exit leg burning in excess of field limits (figure 17), two had exit leg burning (within limits), one had exit leg cracking (within limits), one had exit leg warpage (within limits), and three had no defects. Figure 18 shows the condition of the nine 1200-hour vaporizers and the two non-test vaporizers (No. 2 and No. 4). Because of the excessive exit leg burning, the main fuel manifold was flow checked. The flow checks were performed at 25 p.s.i. for 30 seconds each at a flow rate of 80 lb./hr. All eleven manifold ports flowed 140cc of fuel under the above conditions, thus indicating no manifold blockage. The new vaporizers appear to offer an improvement over the previous standard vaporizers, FSN 2915-977-1044, P/N 1-130-370-01.

i. Combustor Liner Mounting Studs (Flexible and Three-Point-Solid Suspension System), FSN 5306-908-0373, P/N 1-130-096-02 and FSN 5306-908-0374, P/N 1-130-096-03. The combustor liner mounting studs (figure 19) were inspected after accumulating 192.7 hours in engine S/N LE-09753. No damage was evident and the studs were installed in engine S/N LE-10394. After accumulating 600.4 hours, the studs were again removed for inspection. The studs were in good condition and were installed in engine S/N LE-09109. After accumulating 1200 hours, the studs were removed for inspection. They were still in good condition, with no cracking or chafing present. The new eight-point flexible and three-point solid suspension system appears to be an improvement over the preceding system, FSN 2840-979-3740, P/N 1-130-096-01.

j. Combustor Liner, FSN 2840-907-0853, P/N 1-130-600-02. The liner (figure 20) was inspected after accumulating 192.7 hours in engine S/N LE-09753. The only discrepancy found was a 0.093-inch crack in the igniter bracket weld at the 7 o'clock position (figure 21). The stud mounting brackets were in good condition, with no cracks evident. The liner was installed in engine S/N LE-10394. After accumulating 600.4 hours, the liner was again removed for inspection. No additional cracks were noted and the stud mounting brackets were in good condition. The liner was then installed in engine

S/N LE-09109. After accumulating 1200 hours, the liner was removed for inspection. Several small cracks on the plate were noted, but all were within limits (figure 22). Four of the vaporizer seals had broken loose from the liner and were jammed down on the vaporizers (figure 23). The other seven vaporizer seals had worn or broken tabs. The stud mounting brackets were in good condition, with no cracks present. In general, the liner was in good condition after 1200 hours. The modified stud mounting brackets, together with the new studs, offer a definite improvement over the 11-point solid mount liner, P/N 1-130-410-01. Some product improvement is needed to prevent vaporizer seal separation from the liner.

k. Air Seal Segments (Increased Length), FSN 2840-736-3996, P/N 1-140-222-01. The interturbine air seal segments were in good condition at each inspection and after 1200 hours of operation. The spring and seal were both in good condition after 600.4 hours of operation. They were changed as a normal maintenance practice at that time. The engine was cleaned once during the last 599.6 test hours, and there was no evidence of burning caused by walnut shell compound. At the end of the test, the spring tension on the seal was still tight and the seal was in good condition (figure 24). The butted segments appear to offer an improvement over the previous type segments which were wider spaced.

l. Gas Producer (N_1) Tachometer Drive Seal, P/N 4238X. The drive seal operated 192.7 hours in engine S/N LE-09753 and was removed with the reduction gear/compressor section from that engine. The seal was inspected by the engine manufacturer at his facility and was reportedly in good condition except for damage incurred during disassembly. Insufficient test time was accumulated to determine its suitability.

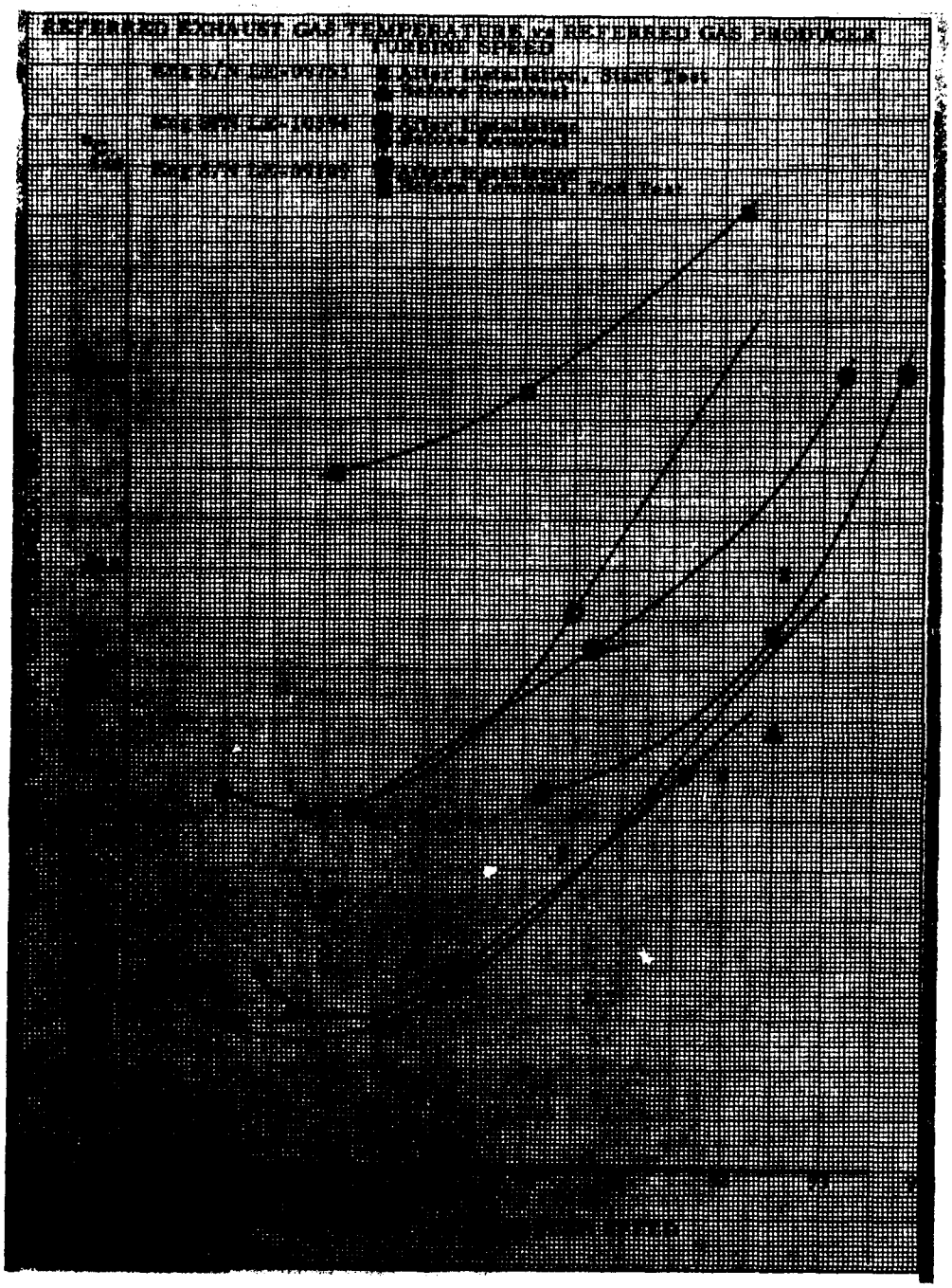

Figure 1.

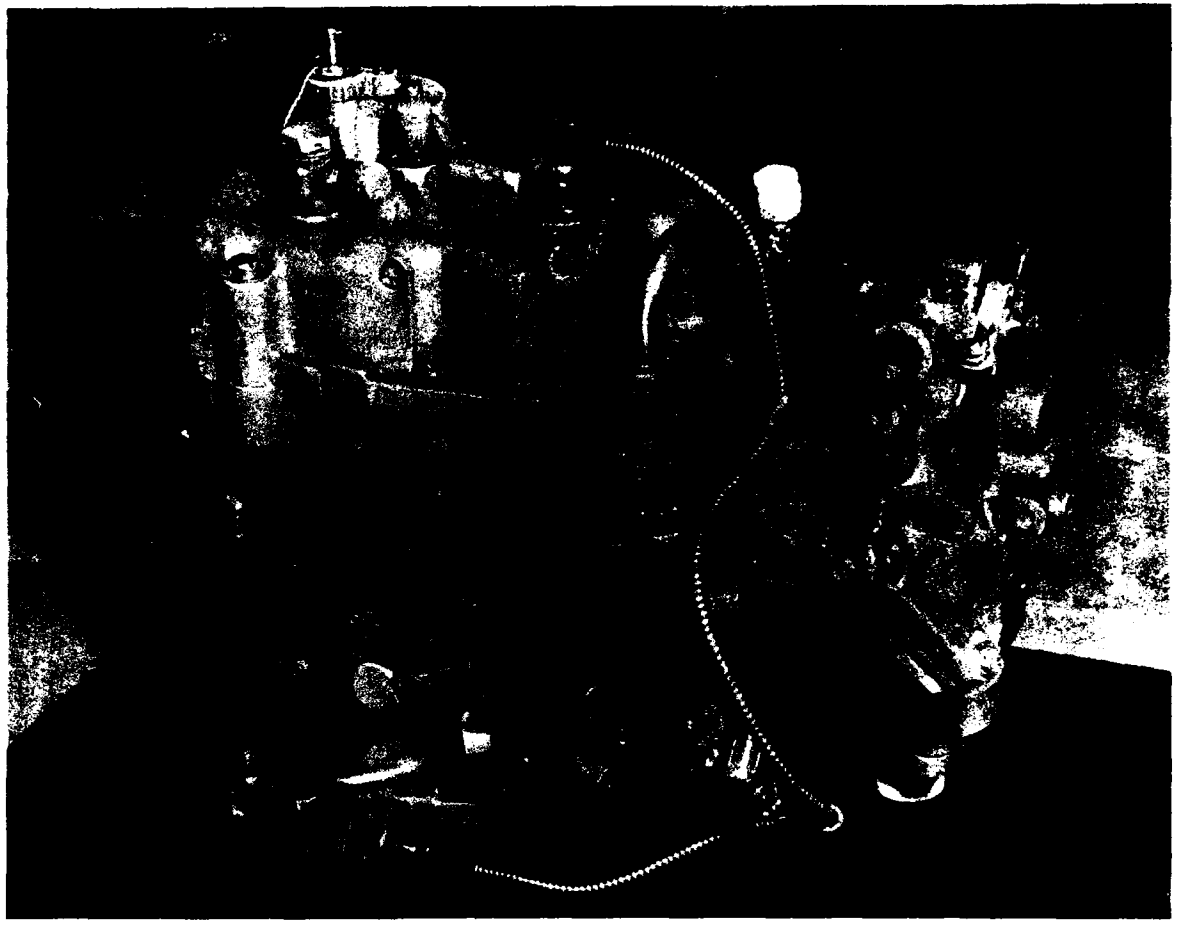

Figure 2. Modified manual fuel control

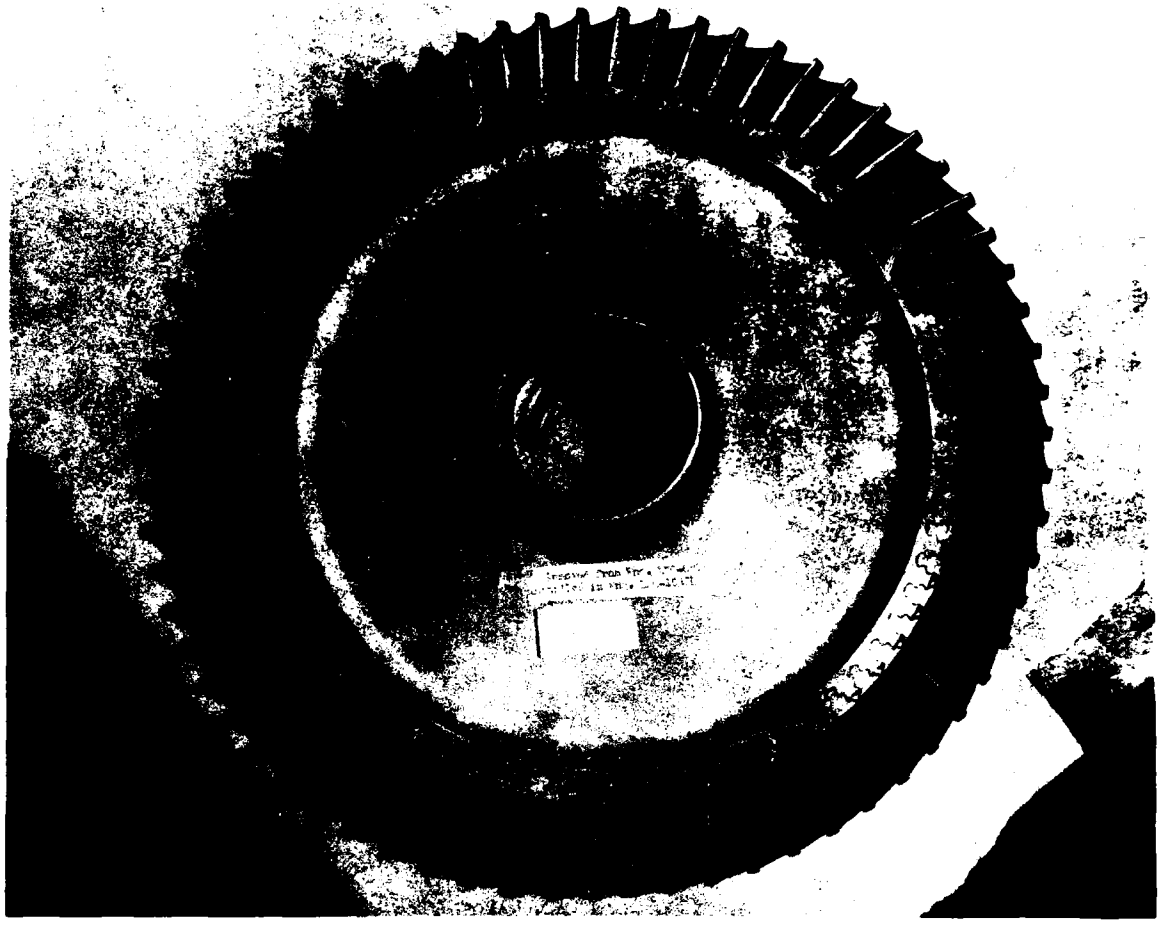

Figure 3. Gas producer turbine wheel, 192.7 operating hours.

Figure 4. Blade erosion on gas producer turbine wheel, 1200.0 operating hours.

Figure 5. Combustor deflector, 192.7 operating hours

Figure 6. Minor cracking in inner flange spot welds of combustor deflector, 1200.0 operating hours.

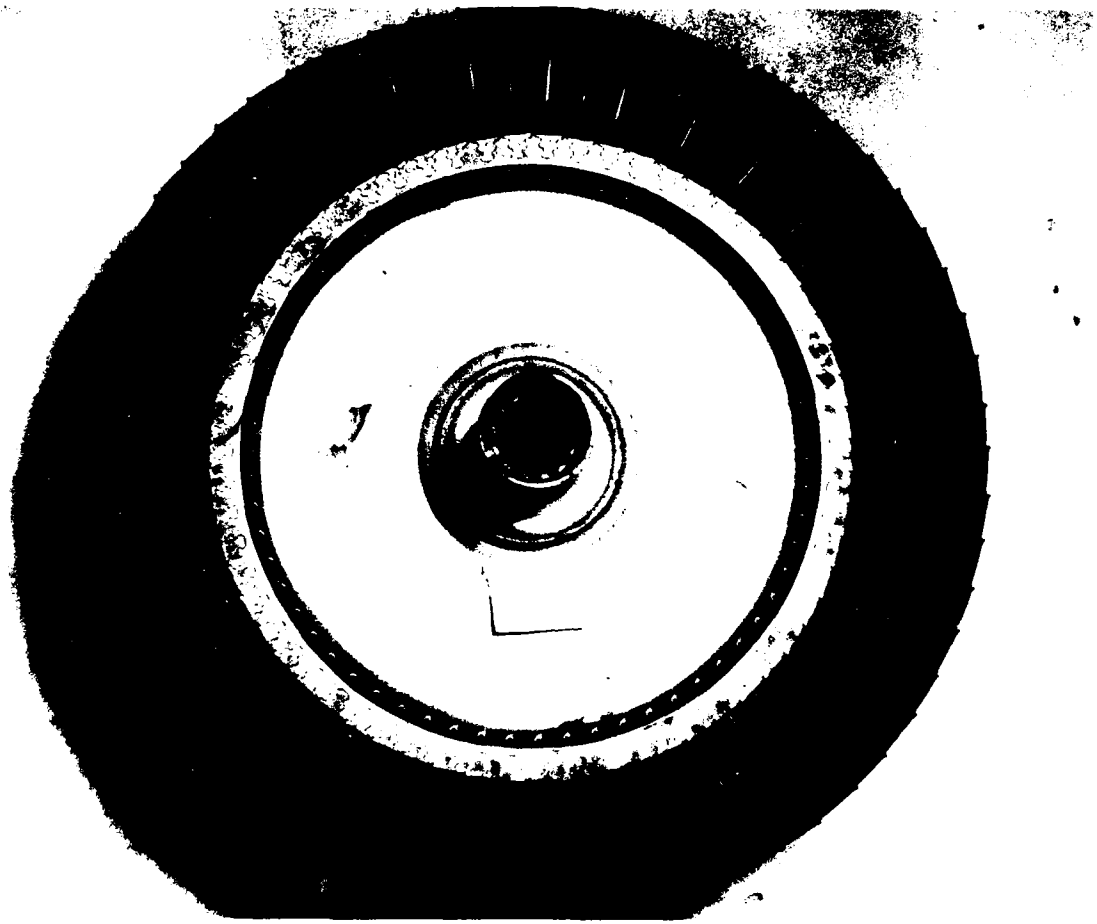

Figure 7. Power turbine wheel, 1200.0 operating hours.

Figure 8. No. 2 mainshaft bearing, 192.7 operating hours

Figure 9. FOD to compressor rotor assembly, 192.7 operating hours.

Figure 10. FOD to compressor rotor assembly, 192.7 operating hours.

Figure 11. Power turbine nozzle, 192.7 operating hours.

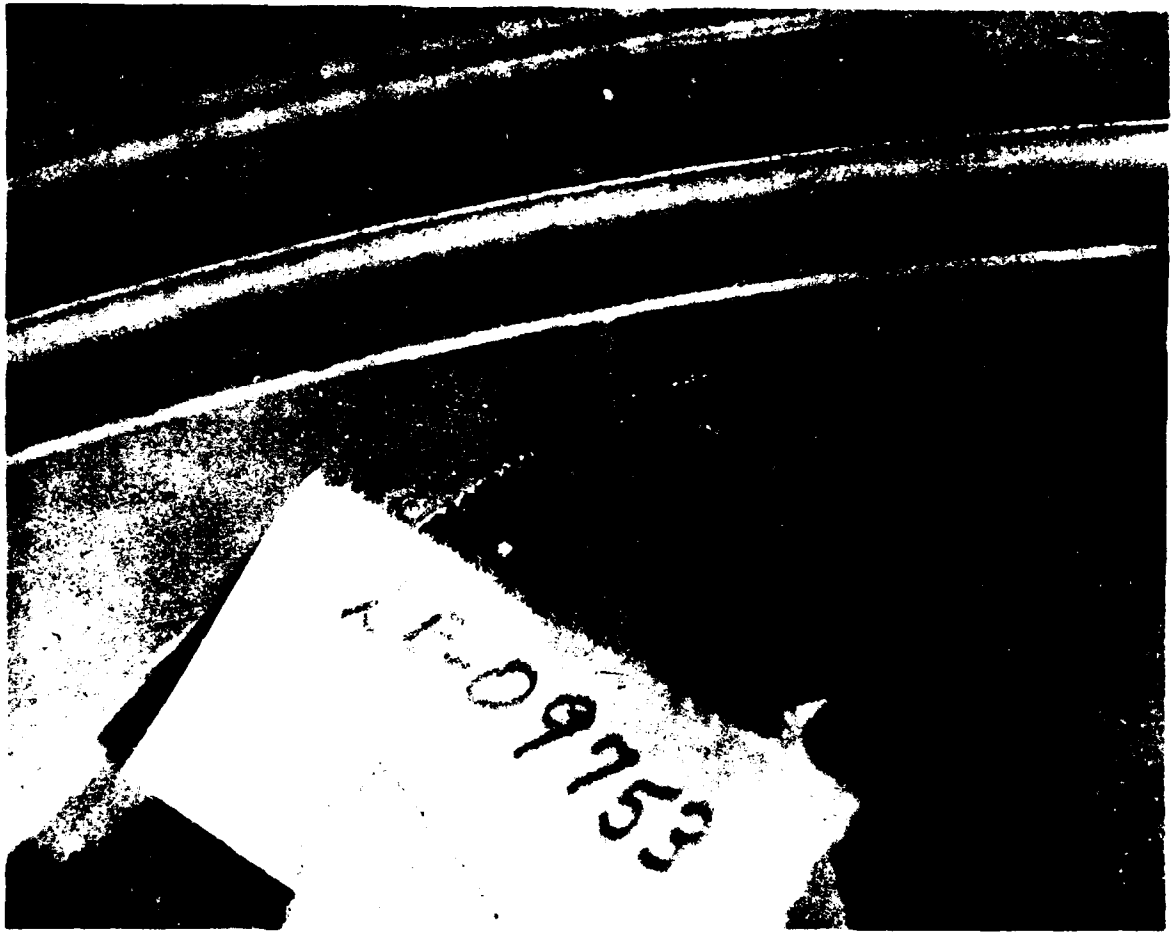

Figure 12. Cracks in vane-to-outboard shroud joint at trailing edge of power turbine nozzle, 192.7 operating hours.

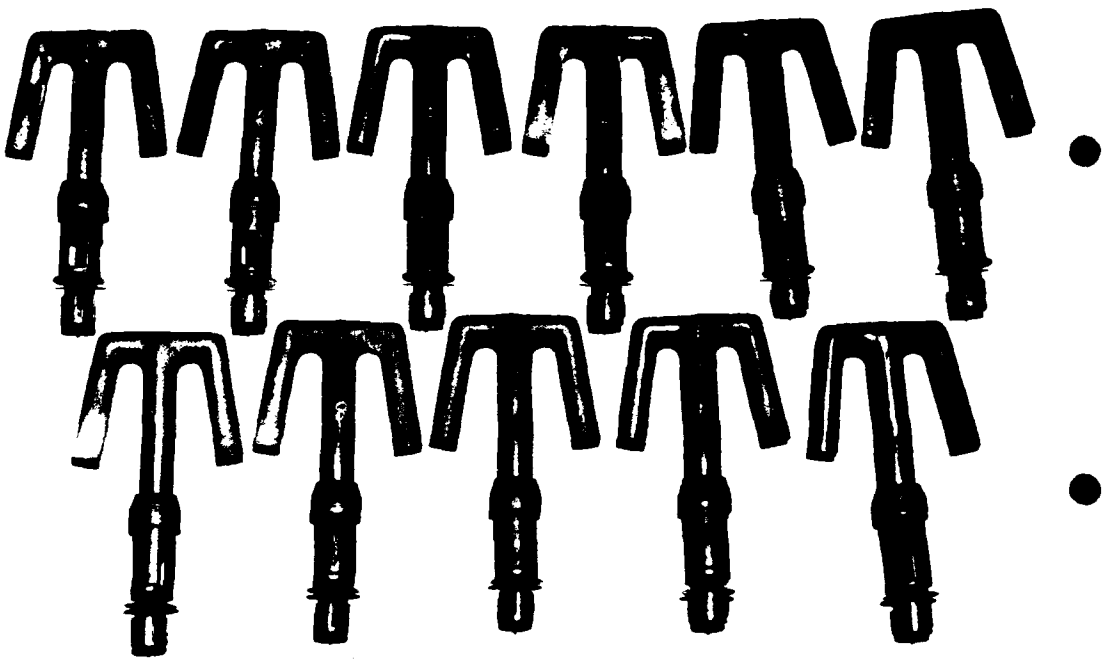

Figure 13. Fuel vaporizers,
192.7 operating hours.

Figure 14. Cracks in welds that attach cooling shroud to vaporizer, 192.7 operating hours.

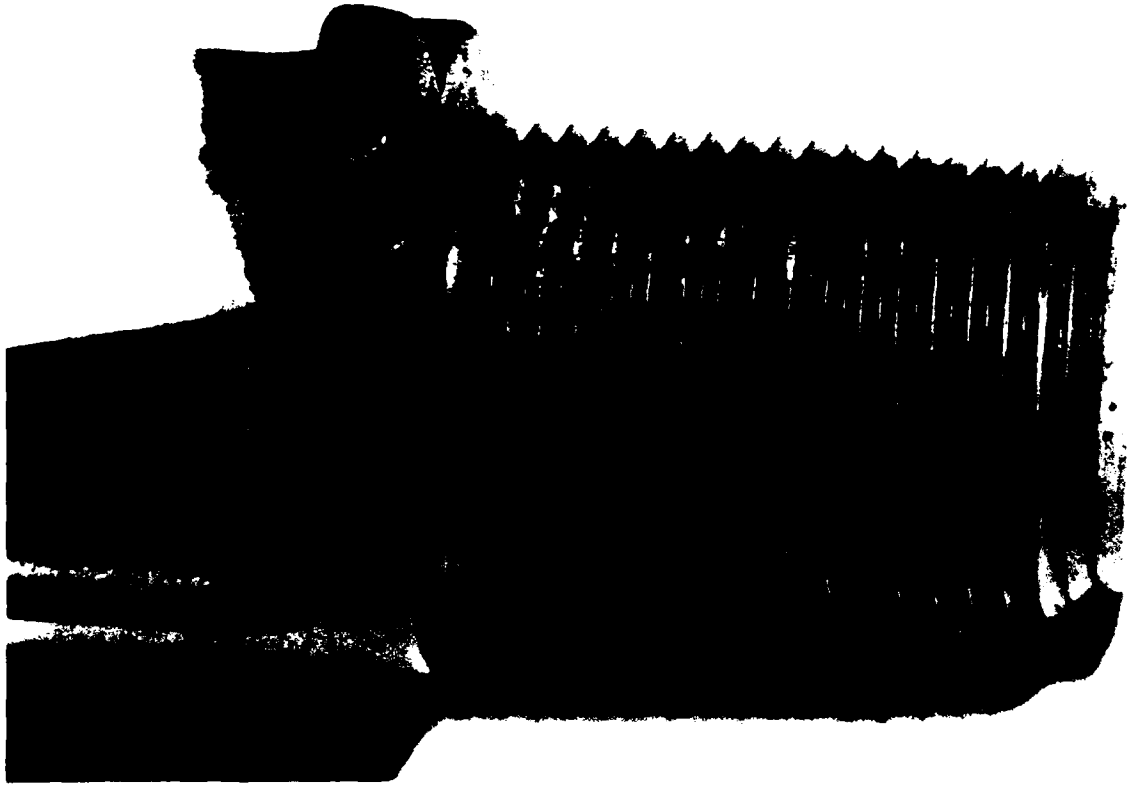

Figure 15. Damaged threads on vaporizer, 192.7 operating hours.

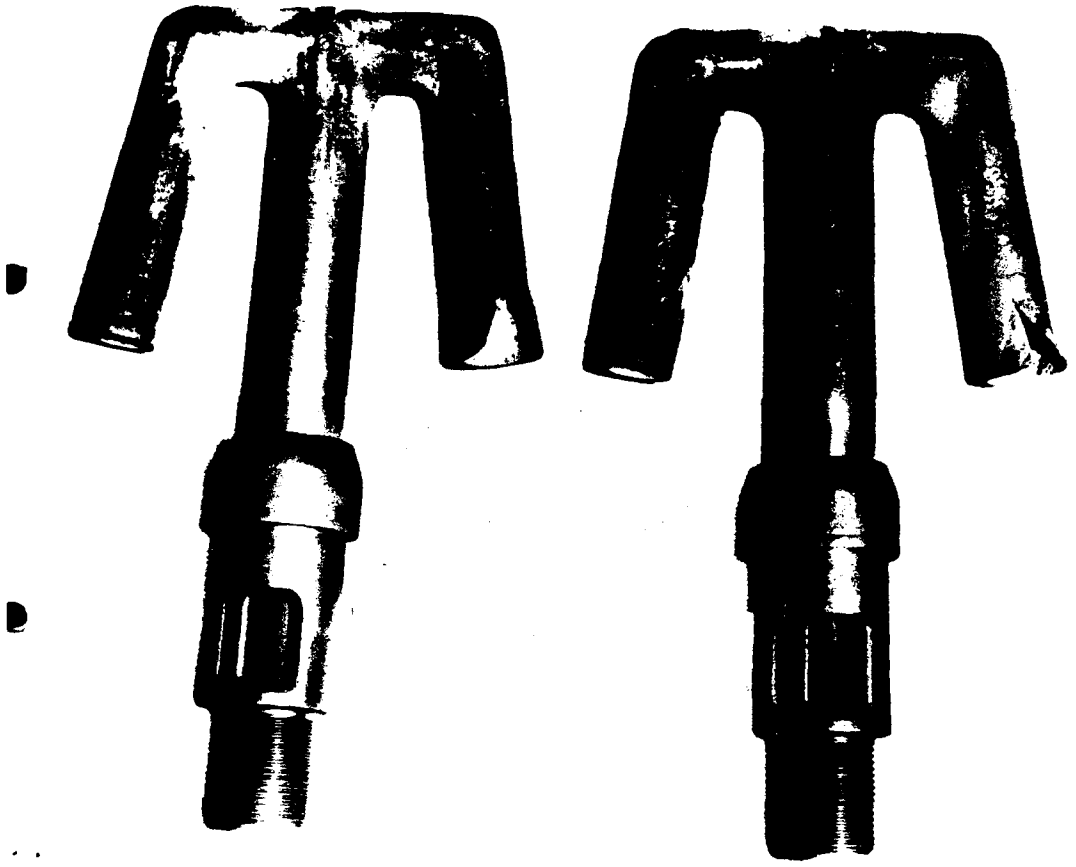

Figure 16. Burned and cracked tips on vaporizer No.'s 2 and 4, 600.4 operating hours.

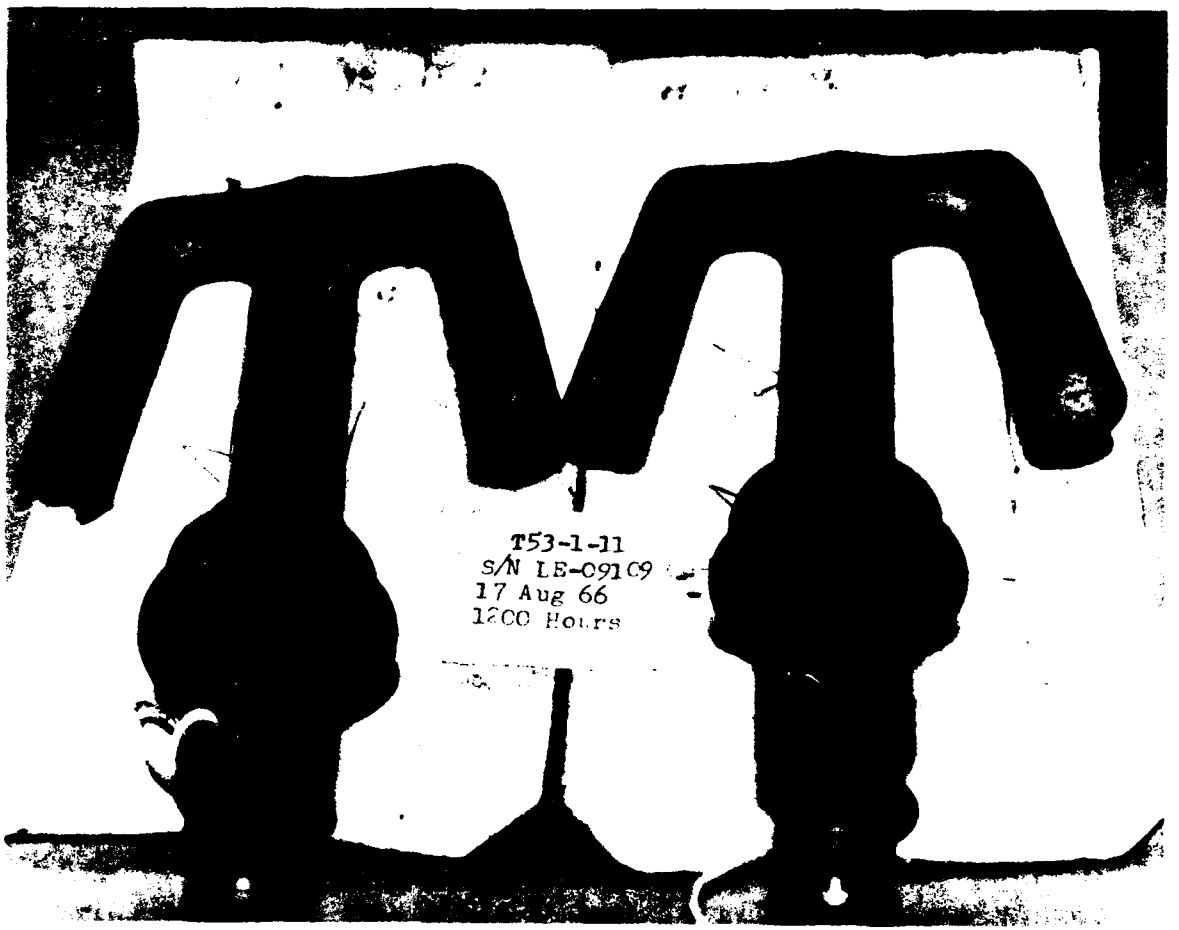

Figure 17. Exit leg burning on vaporizers, No.'s 1 and 11, 1200.0 operating hours.

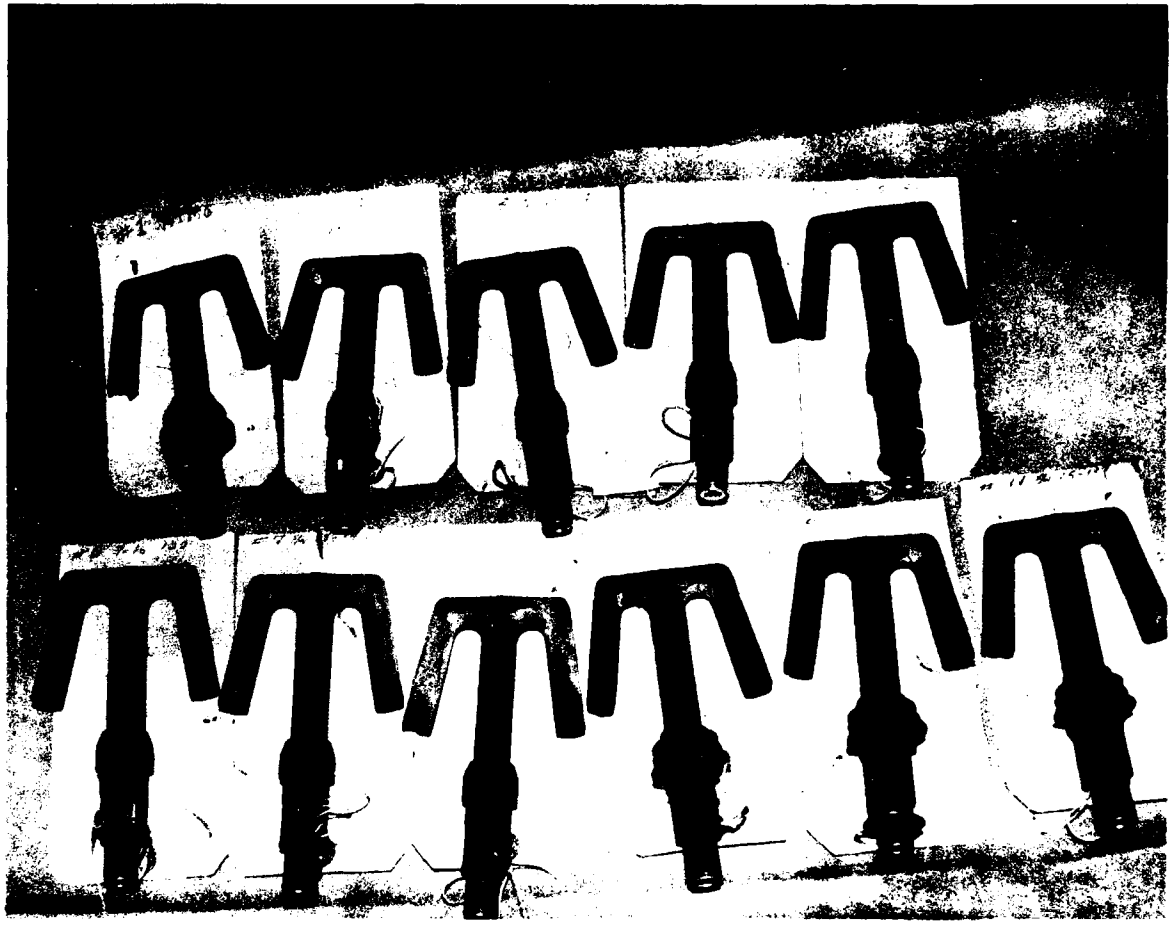

Figure 18. Condition of vaporizers, 1200.0 operating hours. (No.'s 2 and 4 are non-test and had 599.6 operating hours.)

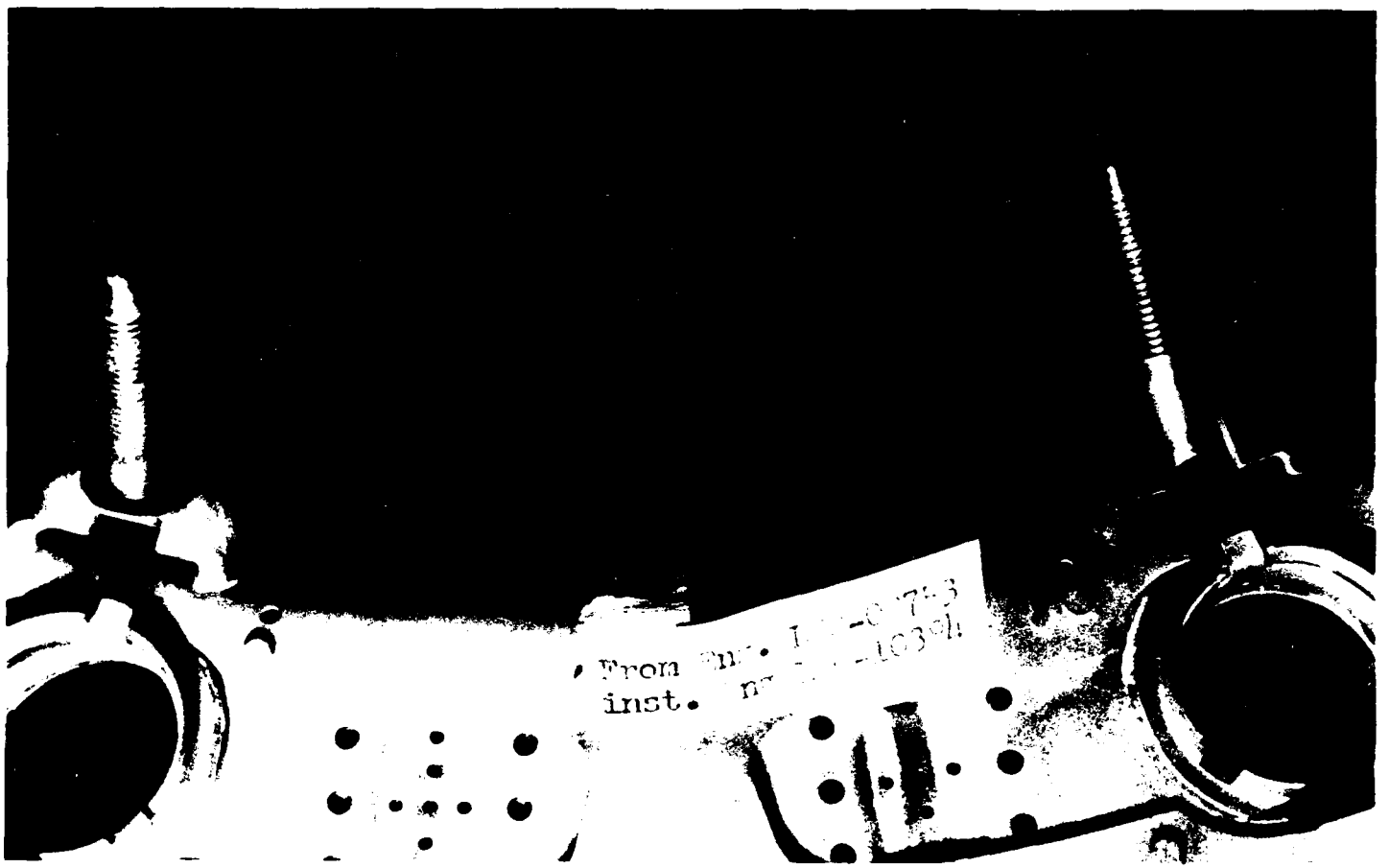

Figure 19. Combustor liner mounting studs, 1200.0 operating hours. (Left stud is flexible mount; right stud is solid mount.)

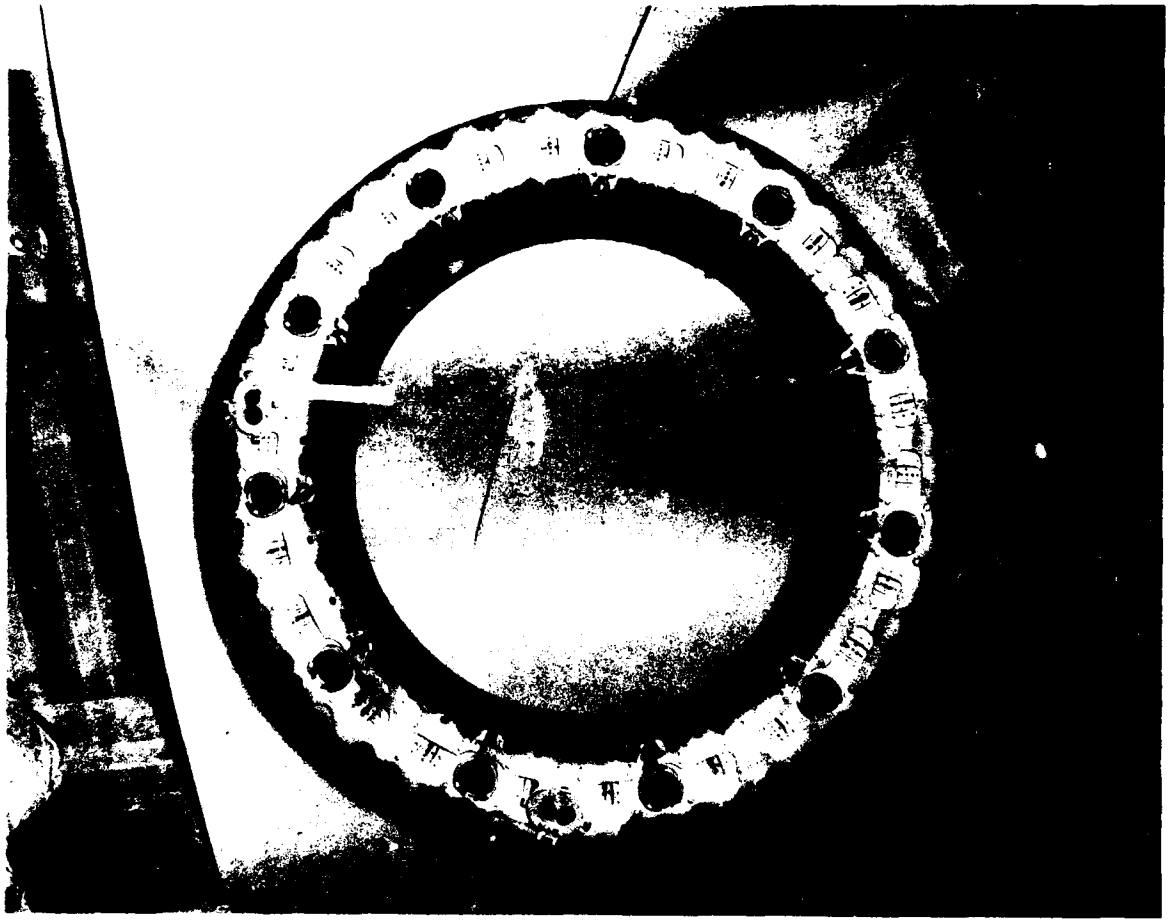

Figure 20. Combustor liner, 192.7 operating hours.

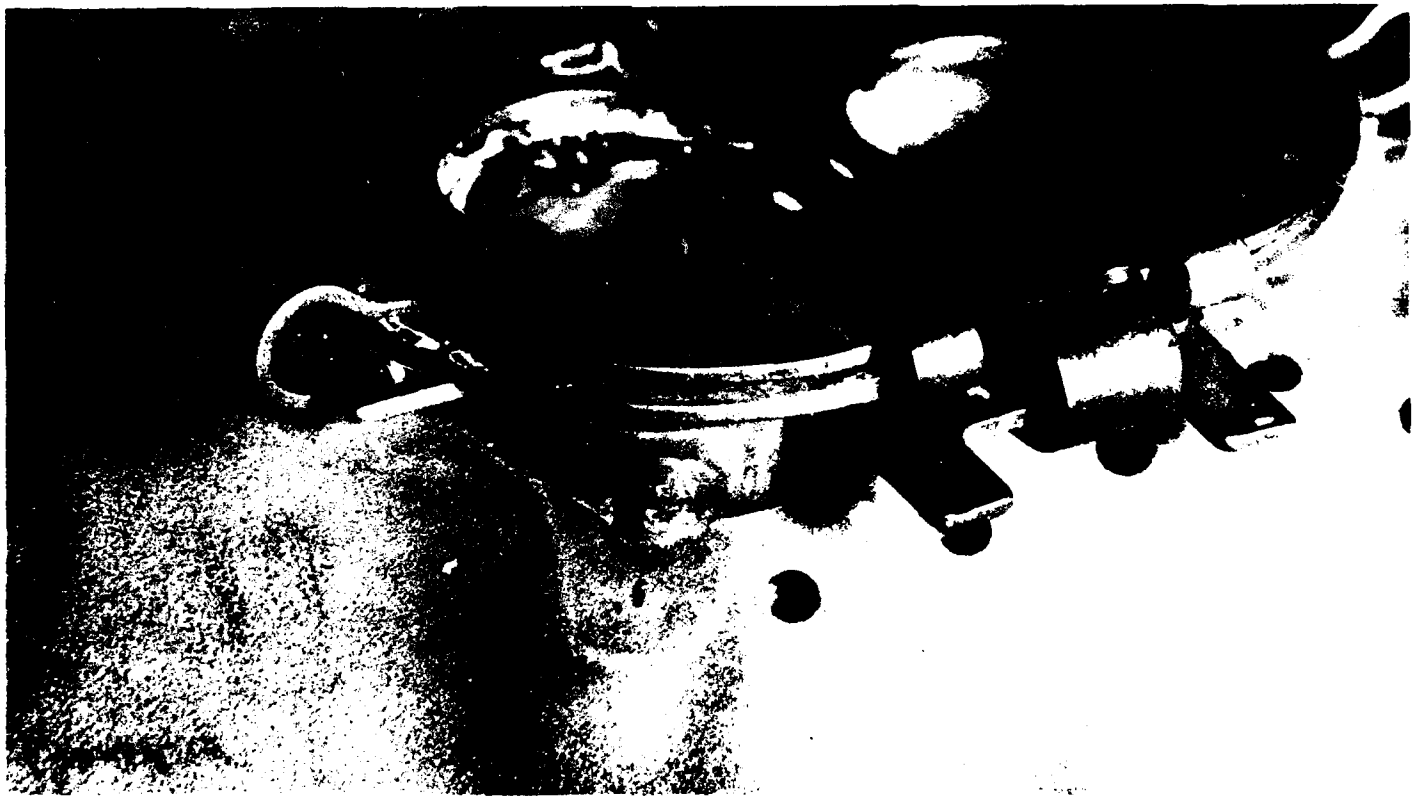

Figure 21. Crack in igniter bracket weld, combustor liner, 192.7 operating hours.

Figure 22. Small cracks on combustor liner plate, 1200.0 operating hours.

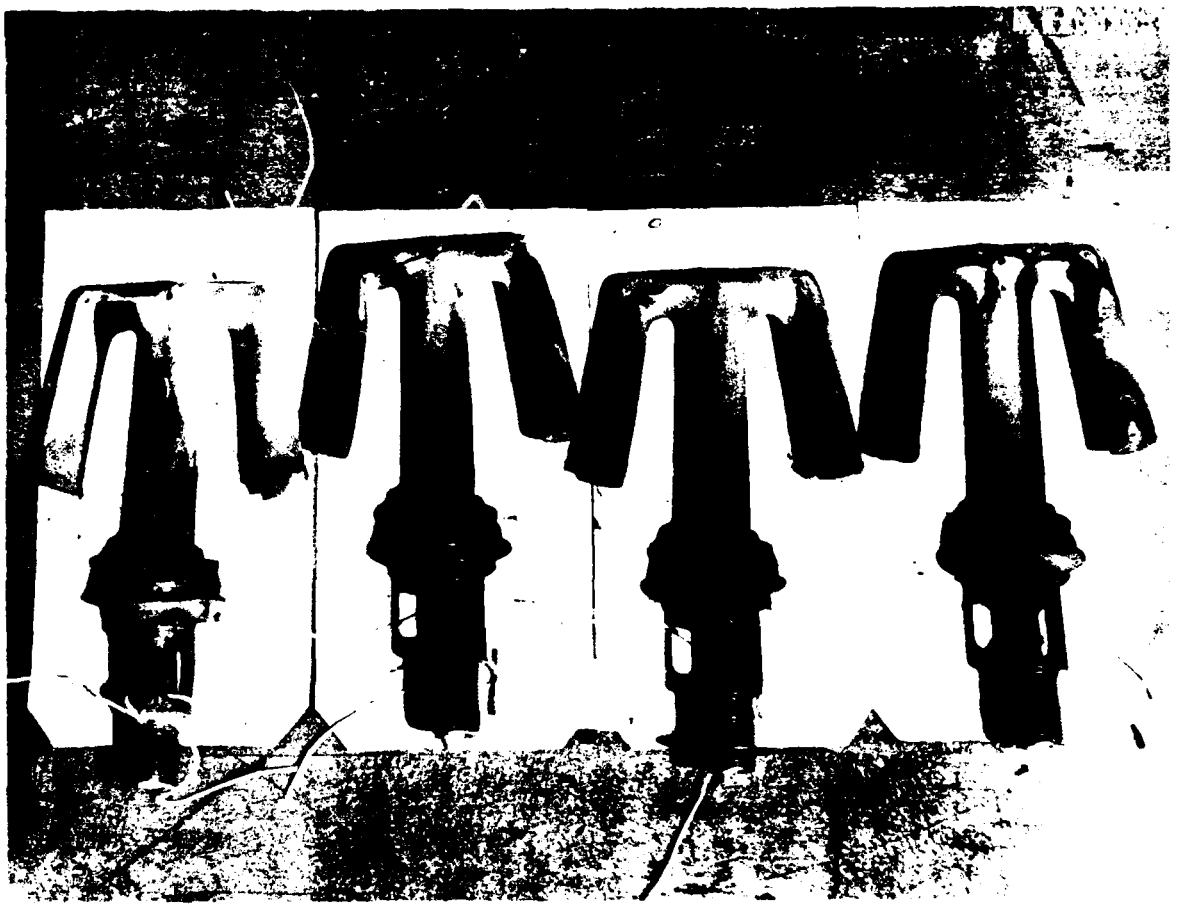

Figure 23. Four vaporizer seals broke loose from liner and jammed down on vaporizers, 1200.0 operating hours.

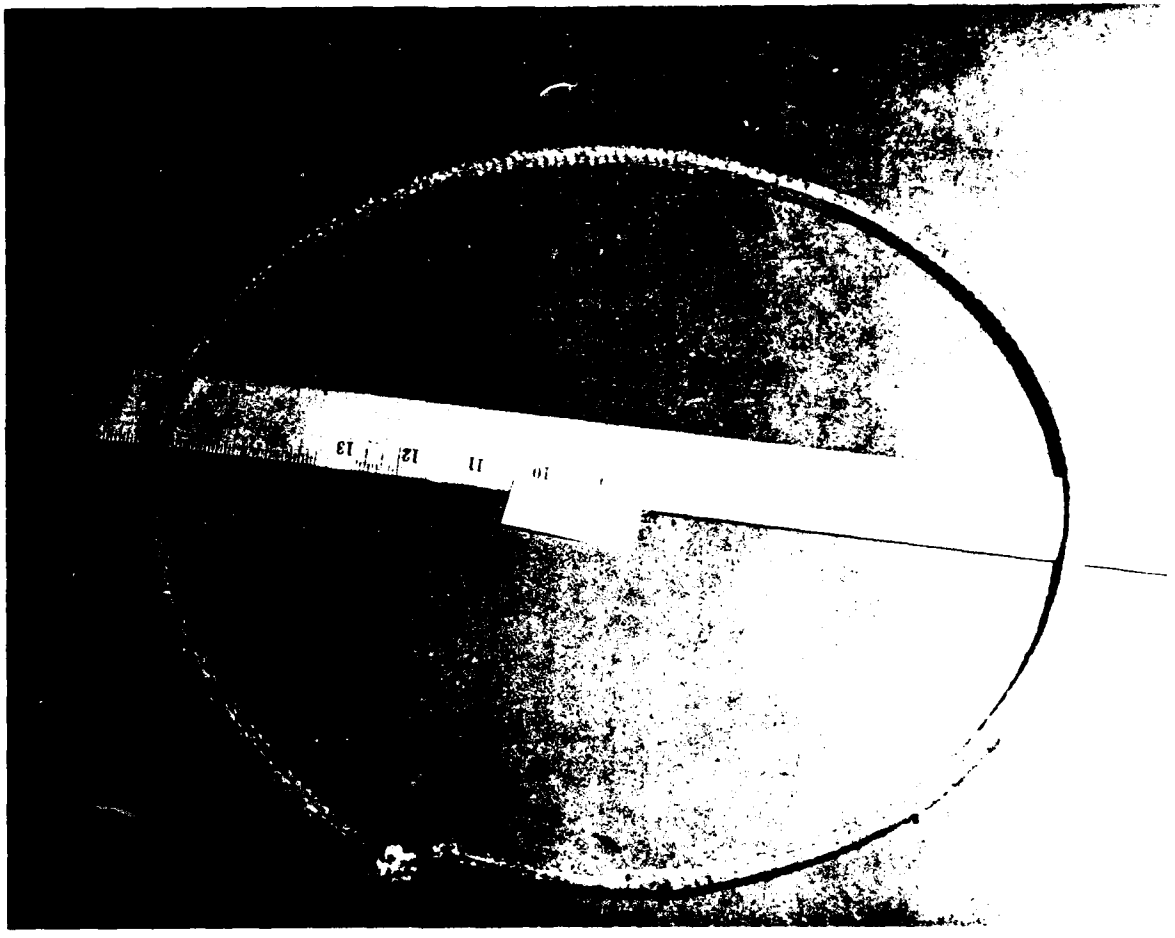

Figure 24. Interturbine air seal, 1200.0 operating hours.